Obesity Surgery (2020) 30:3872–3883
https://doi.org/10.1007/s11695-020-04729-4

ORIGINAL CONTRIBUTIONS

Safety and Efficacy of Bariatric Surgery in Inflammatory Bowel Disease Patients: a Systematic Review and Meta-analysis

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Received: 19 March 2020 / Revised: 16 May 2020 / Accepted: 19 May 2020 / Published online: 23 June 2020

Abstract

Background The safety and efficacy of bariatric surgery in inflammatory bowel disease (IBD) patients is poorly understood. We conducted a systematic review and meta-analysis studying safety and efficacy of bariatric surgery in IBD patients as well as the impact of bariatric surgery on IBD course.

Methods We conducted a comprehensive search of multiple databases (through September 2019) to identify studies that reported outcome of bariatric surgery in IBD patients. Outcomes assessed included the pooled rate of adverse events, change in medications after bariatric surgery, and 12-month excess weight loss (EWL) and body mass index (BMI) reduction after bariatric surgery.

Results A total of 10 studies were included in final analysis. The pooled rate of early and late adverse events was 15.9% (95% CI, 9.3–25.9) and 16.9% (95% CI, 12.1–23.1), respectively. The rate of adverse events in Roux-en-Y gastric bypass was 45.6% (95% CI, 21.9–71.4) compared with 21.6% (95% CI, 11.1–38) in sleeve gastrectomy ($p = 0.11$). The pooled rate of 12-month EWL and BMI reduction after surgery was 66.1% (95% CI, 59.8–72.3%) and 13.7 kg/m^2 (95% CI, 12.5–14.9), respectively. The pooled rate of decrease, increase, and no change of IBD medications were 45.6% (95% CI, 23.8–69.2), 11% (95% CI, 6.3–18.4), and 57.6% (95% CI, 39.2–74.1), respectively.

Conclusions Bariatric surgery has acceptable safety and efficacy profile in IBD patients. Nearly half of patients had decrease in their IBD medications after bariatric surgery, and only 10% experienced therapeutic escalation following bariatric surgery. Sleeve gastrectomy may be the preferred procedure in this population.

Keywords IBD · Crohn's disease · Obesity · Bariatric surgery · Ulcerative colitis · Inflammatory bowel disease

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11695-020-04729-4) contains supplementary material, which is available to authorized users.

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Abbreviations

IBD	Inflammatory bowel disease
UC	Ulcerative colitis
CD	Crohn's disease
RYGB	Roux-en-y gastric bypass
SG	Sleeve gastrectomy
AGB	Adjustable gastric banding
CI	Confidence interval
PI	Prediction interval
GRADE	Grading of recommendations assessment, development and evaluation

Introduction

Obesity is a modern world epidemic and is estimated to affect 35% of individuals worldwide and in the USA [1, 2]. There has been an increasing incidence of inflammatory bowel disease (IBD) over the last decades with reported prevalence of 10–12% per 100,000 person years for both ulcerative colitis (UC) and Crohn's disease (CD) [3–5]. Historically, IBD patients were unlikely to be overweight or obese due to the malabsorption and catabolic disease state; however, the increasing rates of obesity along with enhanced therapeutics over last decades have resulted in higher incidence of obese IBD patients [3, 6]. The prevalence of obesity and severe obesity in IBD patients is estimated at 20–30% and 2–5%, respectively [7–10].

Bariatric surgery is an effective treatment of severe obesity with additional advantages of improvement in metabolic comorbidities and decreased risk of cardiovascular disease [11–13]. There are multiple efficacious bariatric procedures including Roux-en-Y gastric bypass (RYGB), sleeve gastrectomy (SG), and adjustable gastric banding (AGB) [14]. There has been increased utilization of bariatric procedures in the last 7 years ranging from 158,000 procedures in 2011 to 228,000 in 2017 (https://asmbs.org/resources/estimate-of-bariatric-surgery-numbers). Some surgical professional guidelines list CD as relative contraindication for RYGB [15]. Patient factors such as use of immunosuppressant drugs potentially place IBD patients at higher risk of surgical complications [16, 17]. Moreover, underlying nutritional deficiencies in IBD patients may increase susceptibility to further micronutrient deficiencies after bariatric surgery [18, 19]. Co-existent IBD has also been shown to increase the rate of conversion of laparoscopic to open surgeries [20]. Due to the above reasons, bariatric surgery is considered challenging in IBD patients.

Recently, several case series have reported outcomes of bariatric surgery in IBD patients. These studies are limited by small sample size and retrospective nature, preventing definitive assessment of these increasingly common surgical interventions in this increasingly prevalent population. We aimed to conduct a systematic review and meta-analysis assessing the safety and efficacy of bariatric surgery in IBD patients as well as impact of bariatric surgery on IBD course.

Methods

Search Strategy

We conducted a comprehensive search of several databases from inception to September 2019. The databases included Ovid MEDLINE® and Epub Ahead of Print, In-Process and other non-indexed citations, Ovid Embase, Ovid Cochrane Central Register of Controlled trials, Ovid Cochrane Database of Systematic Reviews, and Scopus. Controlled vocabulary supplemented with keywords was used to search for studies of interest. The key words and Mesh terms used were "Inflammatory bowel disease," "bariatric surgery," "RYGB," "gastric bypass," "Crohn's disease," and "ulcerative colitis." The MOOSE checklist was followed and attached in Appendix Table 4 [21, 22].

Study Selection

In this meta-analysis, we included studies that evaluated the clinical outcomes in IBD patients undergoing bariatric surgery. Studies were included regardless of the type of study, inpatient/outpatient setting, and geography so long as the necessary data for analysis was provided .

Studies conducted in pediatric population (age < 18 years), sample size < 2, case reports, and studies not published in English language were excluded. In case of multiple publications from the same cohort or overlapping cohorts, data from the most recent or most appropriate comprehensive report were retained.

Data Abstraction and Quality Assessment

Data on study-related outcomes in the individual studies were abstracted onto a standardized form by two authors (RG, BPM). Two authors (BPM, RG) did the quality scoring independently. Primary study authors were contacted as needed for further information or clarification on data.

The Newcastle-Ottawa scale for cohort studies was used to assess the quality of studies [23]. This quality score consisted of 8 questions, the details of which are provided in Supplementary Table 1.

Outcomes Assessed

1. Pooled rate of early and late adverse events. The early adverse events were defined as any adverse events within 30 days of surgery, whereas adverse events after 30 days

of surgery were classified as late adverse events. These definitions were chosen in accordance with standardized outcomes reporting guidelines by American Society of Metabolic and Bariatric Surgery [24]. We did not further classify the adverse events into major and minor due to limited data and small number of events in included studies. We conducted subgroup analyses by IBD type (CD or UC) when available.

2. Comparison of adverse events between RYGB and SG.
3. Pooled rate of 12-month percent excess weight loss (EWL) and 12-month change in body mass index (BMI) after bariatric surgery.
4. Pooled rate of change in IBD medications after bariatric surgery in terms of decrease of IBD medications, exacerbation, and no change of IBD medications. These definitions were described by individual study authors. Decrease in IBD medications was defined as reduction or de-escalation in IBD medications after surgery as compared to prior to the surgery; exacerbation was defined as need of additional medications or disease flare after surgery (as defined by study authors). Patients were included in no change group if there were no changes in medications after the surgery as compared to before the surgery. Differentiation by type of medication was not available. We included the studies as long as they provided the preoperative and postoperative IBD medications. We also conducted a subgroup analysis by IBD type (CD or UC).

Statistical Analysis

We utilized standard meta-analysis techniques to calculate the pooled estimates in each case following the methods suggested by Der-Simonian and Laird using a random-effects model [25]. When the incidence of an outcome was zero in a study, a continuity correction of 0.5 was added to the number of incident cases before statistical analysis [26]. We assessed heterogeneity between study-specific estimates by using Cochran Q statistical test for heterogeneity, 95% prediction interval (PI), which deals with the dispersion of the effects [27–29], and the I [2] statistics [30, 31]. In this, values of < 30%, 30–60%, 61–75%, and > 75% were suggestive of low, moderate, substantial, and considerable heterogeneity, respectively [32]. Publication bias was ascertained, qualitatively, by visual inspection of funnel plot and quantitatively by the Egger test [33]. When publication bias was present, further statistics using the Fail-Safe N test and Duval and Tweedie's 'Trim and Fill' test was used to ascertain the impact of the bias [34]. Three levels of impact were reported based on the concordance between the reported results and the actual estimate if there were no bias. The impact was reported as minimal if both versions were estimated to be same, modest if effect size changed substantially but the final finding would still remain the same, and severe if basic final conclusion of the analysis is threatened by the bias [35].A p value of < 0.05 was used to define significance.

All analyses were performed using Comprehensive Meta-Analysis (CMA) software, version 3 (BioStat, Englewood, NJ).

Results

Search Results and Population Characteristics

From an initial 46 studies, 26 records were screened and 20 full-length articles were assessed. Ten studies were included in the final analysis, of which 7 were fully published studies whereas 3 were meeting abstracts (Supplementary Figure 1).

A total of 168 IBD patients were included in the analysis from 10 studies [36–45]. Of these, 58% ($n = 99$) had CD and 42% ($n = 69$) had UC (Table 1). The mean age ranged from 39 to 54 years and the majority (78.3%) were female. The average pre-surgery BMI ranged from 41 to 50 and post-surgical follow up ranged 1 to 7 years. The median number of IBD-related surgeries before bariatric surgery was 3.

The most commonly used bariatric procedure was SG (58%, $n = 97$) followed by RYGB (30%, $n = 51$), AGB (12%, $n = 20$), and vertical banded gastroplasty ($n = 1$).

Nine studies reported patient's baseline IBD treatment: 38% ($n = 81$) patients were on any IBD treatment, and 28% ($n = 23$) received preoperative biologic treatment. The details of IBD medications and adverse events after bariatric surgery are shown in Table 2.

Characteristics and Quality of Included Studies

All the 10 studies were retrospective in nature. There were 7 full-length articles and 3 published abstracts. Based on Newcastle-Ottawa scale, 8 studies were of high quality and 2 were medium in quality. Overall quality of evidence was medium.

Meta-analysis Outcomes

The pooled rate of early and late adverse events was 15.9% (95% Confidence Interval (CI), 9.3–25.9) and 16.9% (95% CI, 12.1–23.1), respectively (Fig. 1 a and b) (Table 3). There was numerically higher rate of adverse events in UC group as compared to CD group for both early (31.3% [95% CI, 8.2–69.9] vs. 17.7% [95% CI, 8.1–34.3], $p = 0.2$) and late adverse events (26.5% [95% CI, 13.7–45.1] vs. 20.4% [95% CI, 9.9–37.5], $p = 0.2$), but this did not reach statistical significance (Supplementary Figures 2a, 2b, 3a and 3b).

Individuals who underwent RYGB experienced nearly twice the rate of overall adverse events as compared to SG (45.6% [95% CI, 21.9–71.4] vs. 21.6% [95% CI, 11.1–38]),

Table 1 Showing baseline study characteristics included in the analysis

Author	Year	Type	Number of patients			Mean Age (years)	% female	IBD duration years	Previous IBD treatment					IBD-related surgery	Type of BS with type of IBD			
			total	CD	UC				Total on treatment	No treatment	5-ASA	Immunomodulator	Biologic		RYGB	SG	AGB	VBG
Aelfers et al.	2018	Retrospective	45	29	16	44.1 ± 12.1	82.3	NR	27	18	5	13	3	9	13	26	6	0
Aminian et al.	2016	Retrospective	20	7	13	54 ± 10.5	70	11.3 ± 5.2	11	NR	NR	NR	NR	10	8	9	3	0
Colombo et al.	2015	Retrospective	6	5	1	47.1 ± 8.6	66.6	11.5 ± 8.6	6	0	0	0	4	3	0	5	0	1
Heshmati et al.	2019	Retrospective	54	31	23	46.7 ± 10.9	87	10.2	30	24	25	6	9	8	19	35	0	0
Hudson et al.	2019	Retrospective	13	9	4	48.1 ± 10.6	82	NR	6	7	3	3	2	3	3	9	1	0
Keidar et al.	2015	Retrospective	10	8	2	39.7 ± 11.27	90	6.8	7	3	6	0	1	0	0	9	1	0
Ungar et al.	2013	Retrospective	4	4	0	50.75 ± 13.47	75	11.5 ± 5.4	4	0	2	3	1	1	0	4	0	0
Park et al. (AB)	2013	Retrospective	10	8	2	40.3	80	NR	8	NR	7	1	0	NR	0	10	0	0
Mckenna et al. (AB)	2019	Retrosepctive	33	16	17	51 median	NR	13 median	9	NR	NR	4	3	11	16	14	4	0
Fausel et (AB)	2016	Retrosepctive	18	11	7	49 median	72	6	NR	NR	NR	NR	3	NR	5	2	11	0

AB published abstract, *BS* bariatric surgery, *CD* Crohn's disease, *UC* ulcerative colitis, *IBD* inflammatory bowel disease, *RYGB* Roux-en-Y gastric bypass, *SG* sleeve gastrectomy, *AGB* adjustable gastric banding, *VBG* vertical banded gastroplasty, *5-ASA* 5-aminosalicylic acid, *NR* Not reported

Table 2 Showing the details of assessed outcome of each study included in the analysis

Author	Year	Total number of patients	BMI reduction in 12 months	%EWL in 12 months	Follow up (years)	IBD medications after BS			Adverse events			
						Decrease	Increase	No change	Early (< 30 days)		Late (> 30 days)	
									Total	Comments	Total	Comments
Aelfers et al.	2018	45	NR	62.9 ± 27.1	3.9 ± 3.0	NR	3	NR	8	1 bleeding GE, 3 AKI, 1 passage complaints, 1 WI, 1 anemia, 1 N/V	7	1 PN, 2 passage complaint, 1 hypokalemia, 1 N/V, 1 dehydration, 1 recurring urolithiasis
Aminian et al.	2016	20	14.3 ± 5.7	58.9 ± 21.1	34.6 ± 21.7 months	9	2	NR	7	5 dehydration, 1 PE, 1 WI	5	2 pancreatitis, 2 hernia, 1 marginal ulcer
Colombo et al.	2015	6	13.8 ± 2.0	74.5 ± 11.2	57.8 ± 29.8 months	5	1	0	0	–	1	1 N/V
Heshmati et al.	2019	54	13.2	NR	NR	17	5	32	3	1 gastrointestinal leak, 1 hypoxia, 1 omental infarct	4	1 reversal surgery, 2 abdominal pain,1 fistula
Hudson et al.	2019	13	13.5 ± 6.22	NR	12 ± 1 months	2	0	11	5	1 stenosis, 1 SBO, 3 N/V	3	1 N/V, 1 abscess, 1 band slippage
Keidar et al.	2015	10	NR	71.4 ± 5.6	37.1 ± 22.73 months	3	1	6	1	1 staple line leak	0	–
Ungar et al.	2013	4	12.1 ± 4.04	58 ± 12.74	1.8 ± 1.34	4	0	0	1	1 staple line leak	0	–
Park et al. (AB)	2013	10	NR	86.1	NR	2	0	6	0	–	3	3 diarrhea
Mckenna et al. (AB)	2019	33	NR	63.3 ± 33.1	3.4	NR	0	NR	4	2 SSI, 1 abdominal hematoma, 1 hepatic abscess	7	3 failed gastric band, 2 hernia, 2 gallstones
Fausel et al. (AB)	2016	18	NR	NR	7	NR	6	NR	0	–	0	–

AB published abstract, *BS* bariatric surgery, *NR* not reported, *BMI* basic metabolic index, *IBD* inflammatory bowel disease, *BS* bariatric surgery, *EWL* excess weight loss, *GE* gastroenterostomy, *AKI* acute kidney injury, *WI* wound infection, *N/V* nausea and vomiting, *PE* pulmonary embolism, *SBO* small bowel obstruction, *SSI* skin site infection, *PN* pyelonephritis

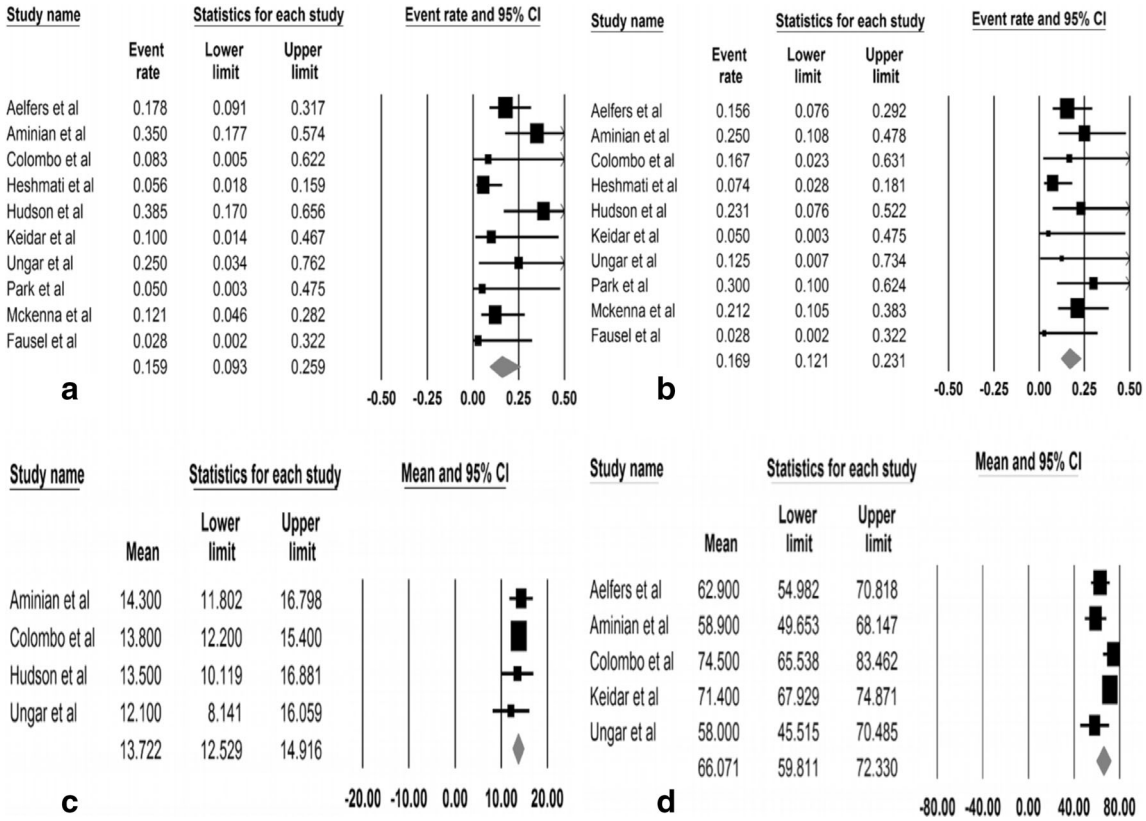

Fig. 1 Pooled rates of early (**a**) and late (**b**) adverse events, change in 12-month body mass index (**c**) and excess weight loss (**d**) after bariatric surgery in all inflammatory bowel disease patients after bariatric surgery

though this did not reach statistical significance ($p = 0.11$). This difference by operative intervention was evident for both early (RYGB 28.9% [95% CI, 14.1–50.1] vs. SG 14.9% [95% CI, 7.8–26.8], $p = 0.2$) and late adverse events (RYGB 26.8% [95% CI, 14.5–44.1] vs. SG 15.0% [95% CI, 8.3–25.8], $p = 0.2$) (Fig. 2a, b, c; Table 3). In order to compare long-term adverse effect of RYGB to SG, we compared late adverse outcomes from studies that had longer than 3 years follow up. RYGB again had higher rate of long-term and late adverse events 24.9% (95% CI, 7.5, 57.5, I2 = 46) as compared to SG

Table 3 Pooled rate of adverse events and changes in IBD medications after bariatric surgery with subgroup analysis

	IBD	UC Subgroup	CD Subgroup	RYGB subgroup	SG subgroup
Adverse events					
Early (< 30 days)	15.9% (9.3–25.9, 46); 10 studies	31.3% (8.2–69.9, 73); 7 studies	17.7% (8.1–34.3, 52); 9 studies	28.9% (14.1–50.1, 54); 5 studies	14.9% (7.8–26.8, 0); 9 studies
Late (> 30 days)	16.9% (12.1–23.1, 0); 10 studies	26.5% (13.7–45.1, 31); 7 studies	20.4% (9.9–37.5, 50); 9 studies	26.8% (14.5–44.1, 37); 5 studies	15.0% (8.3–25.8, 0); 9 studies
Medications after bariatric surgery					
Decrease	45.6% (23.8–69.2, 67); 7 studies	33.8% (10.9–68, 54); 5 studies	47.6% (30.5–65.2, 30); 7 studies	43.8% (9.3–85.6, 60); 3 studies	43% (23.3–65.3, 51); 7 studies
Increase	11% (6.3–18.4, 25); 10 studies	12.6% (5.9–15, 0); 7 studies	18.2% (9.5–32.1, 35); 8 studies	18.1% (7.7–36.9, 0); 4 studies	7.2 (3.1–15.8, 0); 8 studies
No change	57.6% (39.2–74.1, 44); 6 studies	79.1% (62.2–89.7, 0); 4 studies	42.3% (22.5–65, 45); 5 studies	45.6 (11.9–83.8, 52); 3 studies	53.8 (32–74.2, 50); 7 studies

Values are pooled rate (95% CI, I^2); number of studies

IBD inflammatory bowel disease, *CD* Crohn's disease, *UC* ulcerative colitis

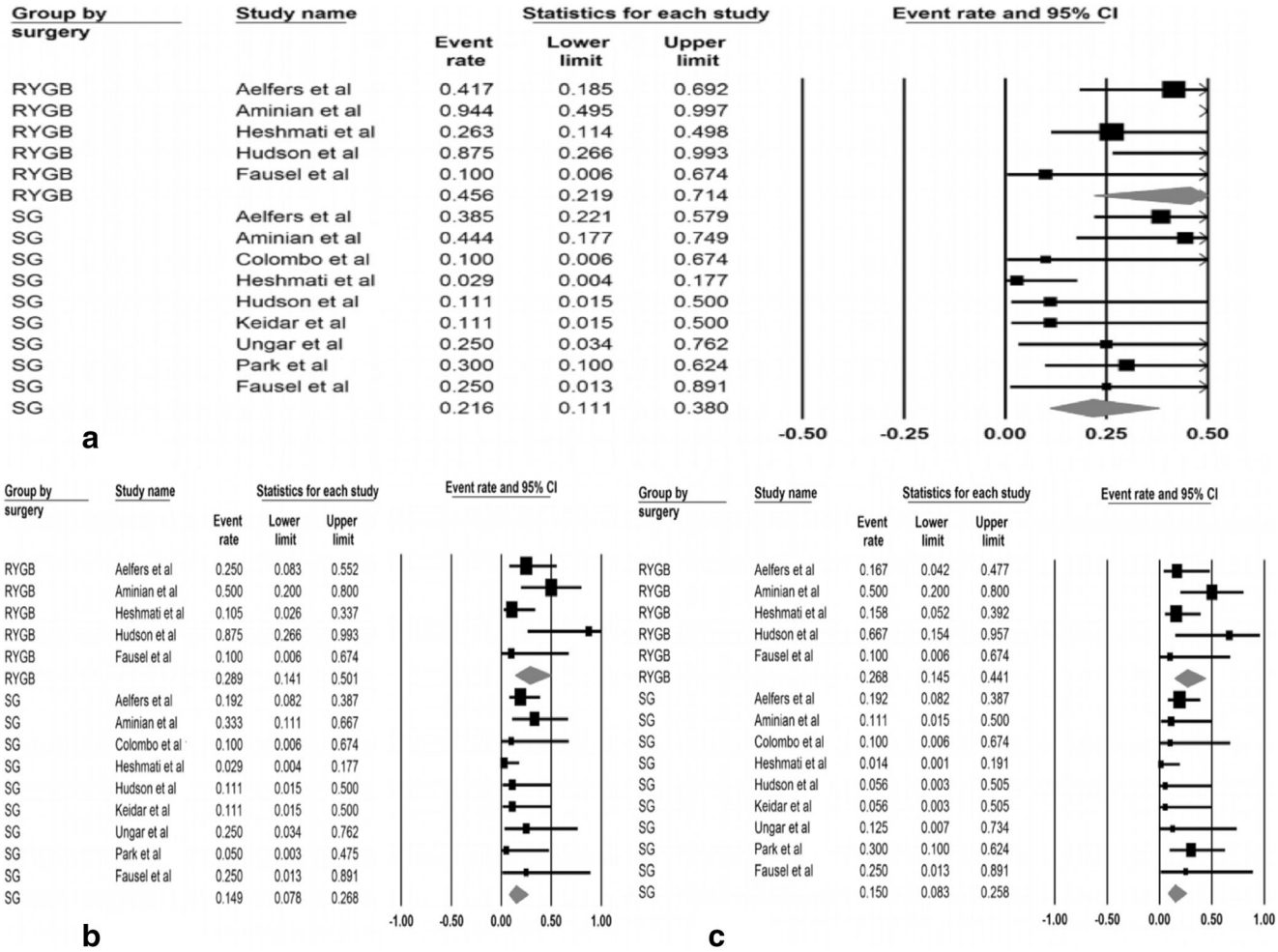

Fig. 2 Pooled rates of all adverse events (**a**), early adverse events (**b**), late adverse events (**c**). After Roux-en-Y gastric bypass and sleeve gastrectomy in inflammatory bowel disease patients

15.2% (95% CI, 7.6, 28.1, I2 = 0), but it did not reach statistical significance.

The pooled rate of 12-month excess weight loss and reduction in BMI after bariatric surgery was 66.1% (95% CI, 59.8–72.3) and 13.7 kg/m^2 (95% CI, 12.5–14.9) respectively (Fig. 1 c and d).

The pooled rates of IBD decrease, increase/exacerbation, and no change in IBD medications were 45.6% (95% CI, 23.8–69.2), 11% (95% CI, 6.3–18.4), and 57.6% (95% CI, 39.2–74.1), respectively (Fig. 3 a, b, and c). On subgroup analysis, the majority (79.1% [95% CI, 62.2–89.7]) of UC cohort had no change in disease activity. However, in CD, 47.6% (95% CI, 30.5–65.2) experienced decrease in IBD medications, 18.2% (95% CI, 9.5–32.1) had increase/exacerbation, and 42.3% (95% CI, 22.5–65) had no change in their IBD medications (Supplementary Figures 4a, 4b, 5a and 5b).

We also performed further subgroup analysis for the IBD disease activity comparing SG and RYGB. There was no significant difference between SG and RYGB in terms of decrease, increase, and no change in IBD medications after bariatric surgery. The rate of decrease in IBD medications after SG and RYGB were 43% (95% CI, 23.3–65.3, $I^2 = 51$) and 43.8% (95% CI, 9.3–85.6, $I^2 = 60$), respectively. There was trend of exacerbation and increase in IBD medications after RYGB (18.1%, 95% CI, 7.7 –36.9, $I^2 = 0$) as compared to SG (7.2%, 95% CI, 3.1–15.8, $I^2 = 0$), but it did not reach statistical significance as evidenced by overlapping confidence intervals. The rates of no change in disease activity were also similar in both groups [SG 53.8%, 95% CI, 32–74.2, $I^2 = 50$) vs. RYGB (45.6%, 95% CI, 11.9 –83.8, $I^2 = 52$)]. These results are also summarized in Table 3.

Validation of Meta-analysis Results

Sensitivity Analysis

To assess whether any one study had a dominant effect on the meta-analysis, we excluded one study at a time and analyzed the consequent effect on the main summary estimate. On this

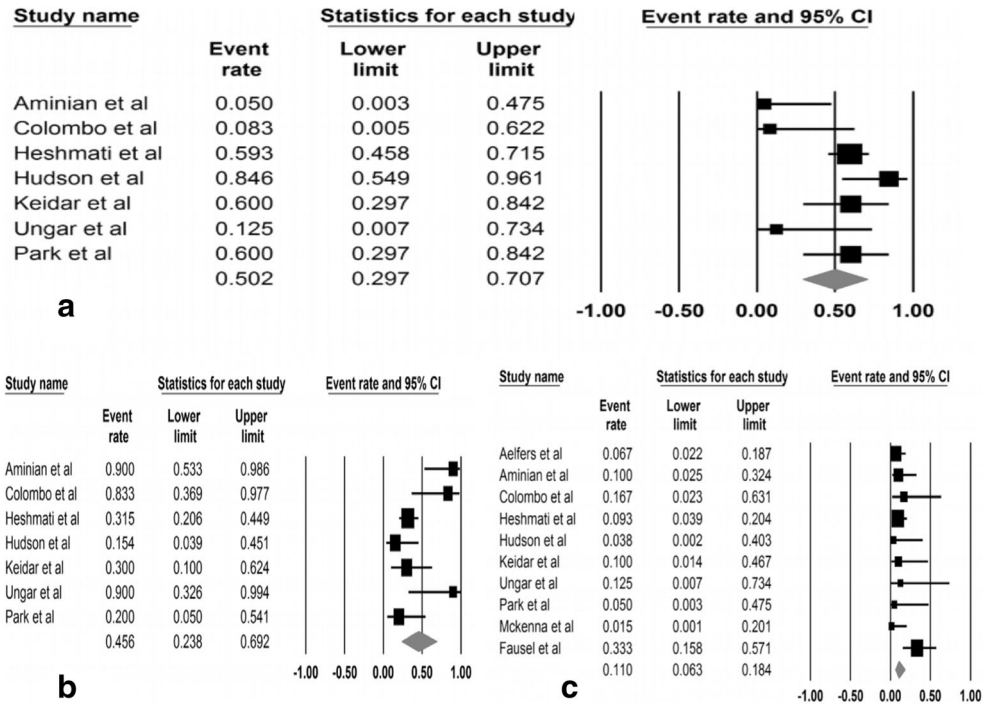

Fig. 3 Pooled rates of no change (**a**), decrease (**b**), and increase (**c**) in inflammatory bowel disease medications after bariatric surgery

analysis, no single study affected the outcome or the heterogeneity.

Heterogeneity

We assessed dispersion of the calculated rates using I^2 percentage values. The I^2 tell us what proportion of the dispersion is true vs chance [29]. The I^2 is reported along with results in Table 3.

Publication Bias

There was no evidence of publication bias in the collected studies or outcomes based on the quantitative Egger's test ($p = 0.6$) and Funnel plot (Supplementary Figure 6).

Discussion

In this meta-analysis of 10 studies, bariatric surgery appears safe and effective in patients with known IBD. The current data suggest that SG may be the preferred intervention compared to RYGB due to potentially fewer adverse events. With the increasing prevalence of obese IBD patients, bariatric surgery is likely to become a frequently encountered scenario. These results will help guide IBD patients and clinicians when navigating weight management options.

The rate of early and late adverse events after bariatric surgery in IBD patients was 15.9% and 16.9% respectively. We could not further categorize adverse events into major or minor due to missing data in the studies and very small number of events. Interestingly, there were more adverse events in UC patients as compared to CD group though this did not reach statistical significance. The exact reason for this potential difference is unknown. One explanation could be that some UC patients had prior extensive total colectomy that could make the subsequent bariatric surgical procedures technically challenging. The reported complication rate in general population after bariatric surgery ranges from 10 to 17% and from 0 to 37% in a systematic review and Cochrane analysis [46, 47]. Another study also reported acceptable safety profile of bariatric surgery in IBD with significant higher risk of perioperative small bowel obstruction without any difference in inpatient mortality [48]. Thus, bariatric surgery in IBD appears to have similar safety profile as in general population.

The reported EWL of various bariatric surgery ranges from 30 to 80% for various bariatric surgeries [12, 46, 49, 50]. Our result of 66% EWL 12 months post-surgery is in alignment with reported literature in non-IBD patients. Thus, bariatric surgery seems to be equally effective in IBD patients as the general population. Given the increasing obesity and consequently increased rates of metabolic comorbidities in the IBD population, it is imperative to understand different weight loss therapies including bariatric surgical options to improve long-term health outcomes.

One of the major concerns with bariatric surgery in IBD is safety given the luminal inflammation and immune-modifying medications typically utilized. A systematic review reported a rate of 10–21% of any postoperative complications in obese non-IBD patients after bariatric surgery [46]. We also

found relatively low risk of postoperative complications (15.9%–16.9%) in IBD patients who underwent bariatric surgery similar to non-IBD patients, potentially reflecting no increased risk of complications in IBD. Furthermore, bariatric surgery has been reported to reduce morbidity in terms of renal failure, malnutrition, and fistula formation in morbidly obese IBD patients [51]. Together, bariatric surgery may be safe, effective, and potentially positively influence disease course.

SG was the most commonly performed procedure for weight loss in our study and demonstrated numerically fewer adverse outcomes compared to RYGB. There was a higher trend of disease worsening in patients who underwent RYGB as compared to SG but did not reach statistical significance. In addition to potential improved outcomes and reduced potential risk of exacerbation, SG also preserves the future operative options by not altering small bowel anatomy in CD patients. In addition, RYGB may predispose to intestinal bacterial overgrowth that may precipitate IBD disease activity [6, 52, 53]. Based on the available data, SG may be the preferred procedure in IBD patients who desire weight loss surgery, if there is no reason favoring other bariatric surgical procedures.

We also report the effect of bariatric surgery on IBD medications. Overall, in half of patients, bariatric surgery had no effect on IBD medications, whereas 45% had decrease and 11% experienced increase in their IBD medications. On subgroup analysis, CD seemed more sensitive to the bariatric intervention with numerically higher rates of induced decrease and increase of their IBD medications whereas the majority of UC patients experienced no changes in their medications after bariatric surgery. The differential impact of bariatric surgery on IBD medications would be explained by the fact that many UC patients had total colectomy or had inactive form of disease before bariatric surgery. The reason of why some patients experience decrease and others experience increase of IBD medications is unclear and poorly understood. Obesity itself is known to be chronic inflammatory state and may influence IBD activity and disease course [54–58]. This is due to complex interplay of gut microbiota, bile acids, intestinal hormones, and the immune system [59–61]. Mesenteric adipose tissue hypertrophy in CD patients may also mediate key intestinal inflammatory processes [62–65]. Moreover, obesity itself increases operating times, increases technical complexity, and risk of complications [7, 66]. Consequently, bariatric surgery and subsequent weight loss may influence these factors and improve inflammation [67–69]. These results are reassuring and encouraging for IBD patients undergoing bariatric surgery and strongly reiterate the role of obesity and inflammation.

There are limitations to this study. All studies included in the analysis were retrospective introducing the risks of such observational studies. There were no uniform selection criteria for patients undergoing bariatric surgery. There were missing data for outcomes in many studies specifically on medications. In addition, we were not able to account for real IBD related activity and had to rely on changes in medications as surrogate for disease activity as described by study authors. Current standards of evaluating disease activity include endoscopic assessment, surrogate biomarkers, and radiographic disease activity which were not available for the included studies. This further limits the assessment of the impact of bariatric surgery on IBD activity and is an area of future study. We were also not able to account for impact of biologics due to limited data but our data is reassuring for IBD patients with obesity interested in bariatric surgery. Most included studies were performed at tertiary-care referral centers potentially limiting generalizability. All studies were published within the last 5 years and include historical patients. Thus, sensitivity analysis based on potential temporal or secular influences was not feasible.

The strengths of this review include the systematic literature search with well-defined inclusion criteria, careful exclusion of redundant studies with detailed extraction of data, and rigorous evaluation of study quality. This is the most updated systematic review on bariatric surgery in IBD patients.

In conclusion, the current meta-analysis demonstrates the safety and efficacy of bariatric surgery in IBD patients with relatively similar rate of adverse events and weight loss as non-IBD obese patients. The data is encouraging for both obese IBD patients and their clinicians considering bariatric surgery. SG may be associated with less adverse outcomes as compared with RYGB and would be considered as preferred procedure in this population.

Acknowledgments The authors thank medical librarian Loren Hackett, MLIS, AHIP for assisting us in literature search.

Author Contributions RG, BC: conception and design, drafting of article.
RG, BPM: study search, review, and selection.
RG, BPM: data collection and synthesis.
BPM, SP: statistical analysis of data and interpretation of results.
All authors: critical revision of the article for important intellectual content and final approval of the article.

Compliance with Ethical Standards

Conflict of Interest MR has received research support from Abbvie, Janssen, Takeda, Pfizer Unrestricted Educational Grants from Abbvie, Janssen, UCB, Pfizer, Takeda, Salix, Shire Advisory Boards and Consultant for Abbvie, Janssen, UCB, Takeda, Pfizer, Miraca Labs, Amgen, Celgene, Seres, Allergan, Genentech, Gilead, Salix, and Prometheus.

BC is consultant for Takeda and TARGET PharmaSolutions along with speakers bureau for Takeda.

RG, BPM, SP, AA and AS has nothing to disclose.

Ethical Approval For this type of study, formal consent is not required.

Informed Consent Informed consent does not apply.

Appendix

Table 4 MOOSE Checklist for Meta-analyses of Observational Studies

Item No	Recommendation	Reported on Page No
Reporting of background should include		
1	Problem definition	6
2	Hypothesis statement	-
3	Description of study outcome(s)	7
4	Type of exposure or intervention used	7
5	Type of study designs used	7-8
6	Study population	8
Reporting of search strategy should include		
7	Qualifications of searchers (eg, librarians and investigators)	1
8	Search strategy, including time period included in the synthesis and key words	6
9	Effort to include all available studies, including contact with authors	7
10	Databases and registries searched	6
11	Search software used, name and version, including special features used (eg, explosion)	6
12	Use of hand searching (eg, reference lists of obtained articles)	6
13	List of citations located and those excluded, including justification	8, Table 2, Fig 1
14	Method of addressing articles published in languages other than English	-
15	Method of handling abstracts and unpublished studies	6
16	Description of any contact with authors	6
Reporting of methods should include		
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	5-8
18	Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	6-8
19	Documentation of how data were classified and coded (eg, multiple raters, blinding and interrater reliability)	6-8
20	Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	7
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	5
22	Assessment of heterogeneity	8
23	Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	8
24	Provision of appropriate tables and graphics	Tables 1-3, Figs 1-5
Reporting of results should include		
25	Graphic summarizing individual study estimates and overall estimate	Figs 1-5
26	Table giving descriptive information for each study included	Table 1 and 2
27	Results of sensitivity testing (eg, subgroup analysis)	Fig 3, 8
28	Indication of statistical uncertainty of findings	10-12
Item No	**Recommendation**	**Reported on Page No**
Reporting of discussion should include		
29	Quantitative assessment of bias (eg, publication bias)	8
30	Justification for exclusion (eg, exclusion of non-English language citations)	6
31	Assessment of quality of included studies	9
Reporting of conclusions should include		
32	Consideration of alternative explanations for observed results	10-12
33	Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	12
34	Guidelines for future research	12
35	Disclosure of funding source	1

From: Stroup DF, Berlin JA, Morton SC, et al., for the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group. Meta-analysis of Observational Studies in Epidemiology. A Proposal for Reporting. JAMA. 2000;283 (15):2008–2012. doi: https://doi.org/10.1001/jama.283.15.2008

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